ESA CAPACITY study

Composition of the Atmosphere: Progress to Applications in the User CommunITY

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ESA CAPACITY study

Operational atmospheric chemistry monitoring

User requirements
Contributions of current and planned missions
Mission concepts and instrument requirements

Time frame: 2010-2020

Study consortium

Prime : KNMI (H. Kelder, M. van Weele, A. Goede)

Core team :
Rutherford-Appleton Lab (B. Kerridge, J. Reburn)
Univ. Leicester (P. Monks, J. Remedios)
Univ. Bremen (H. Bovensmann)
EADS-Astrium (R. Mager)
Alcatel Space (H. Sassier)

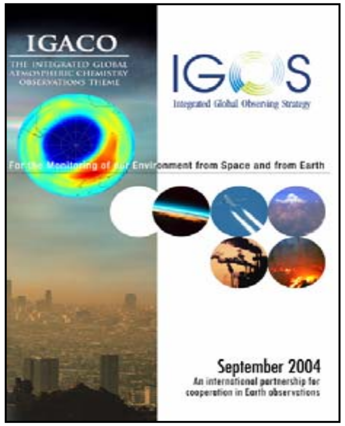
Consultants:
Requirements – WMO, JRC, 5 weather and environmental agencies, Eurocontrol, 11 research institutes and universities

Space instrumentation – 10 research institutes and universities, 1 company

Ground instrumentation – 1 research institute

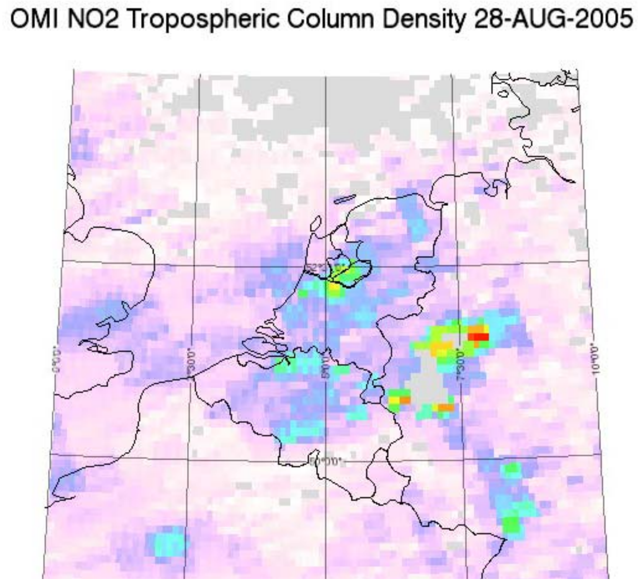
ESA Joerg Langen

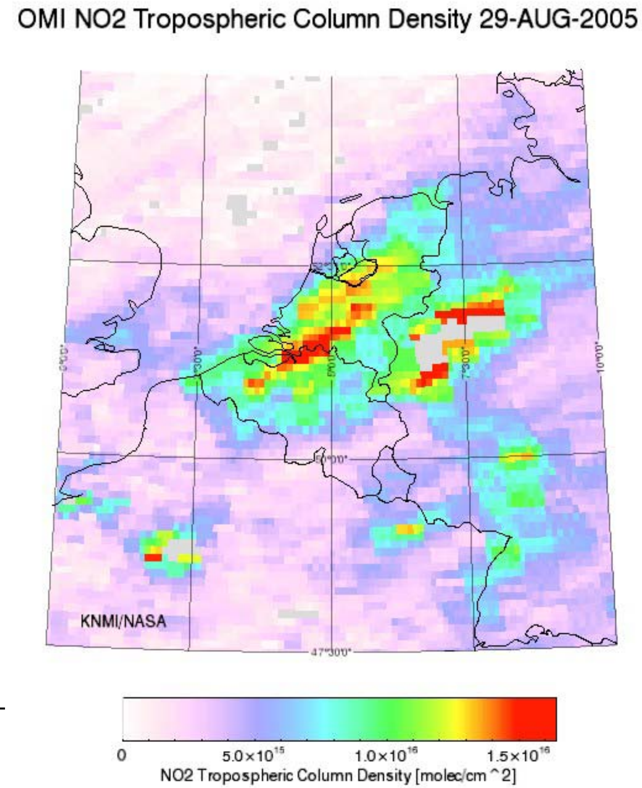
Sources of user and observational requirements



- IGOS-IGACO Theme report
- EU GMES-GATO report
- EU FP projects, e.g. Create-Daedalus, Evergreen
- EUMETSAT user consultation in the frame of MTG
- Environment and climate protection protocols, directives etc. (EU, international)
- GCOS implementation plan, WCRP-SPARC long-term observation requirements
- GMES service element PROMOTE
- ESA studies on CO_2 monitoring
- ESA study on atmospheric chemistry observation requirements (research)
- CAPACITY workshop Jan. ’04 and final presentation June ‘05

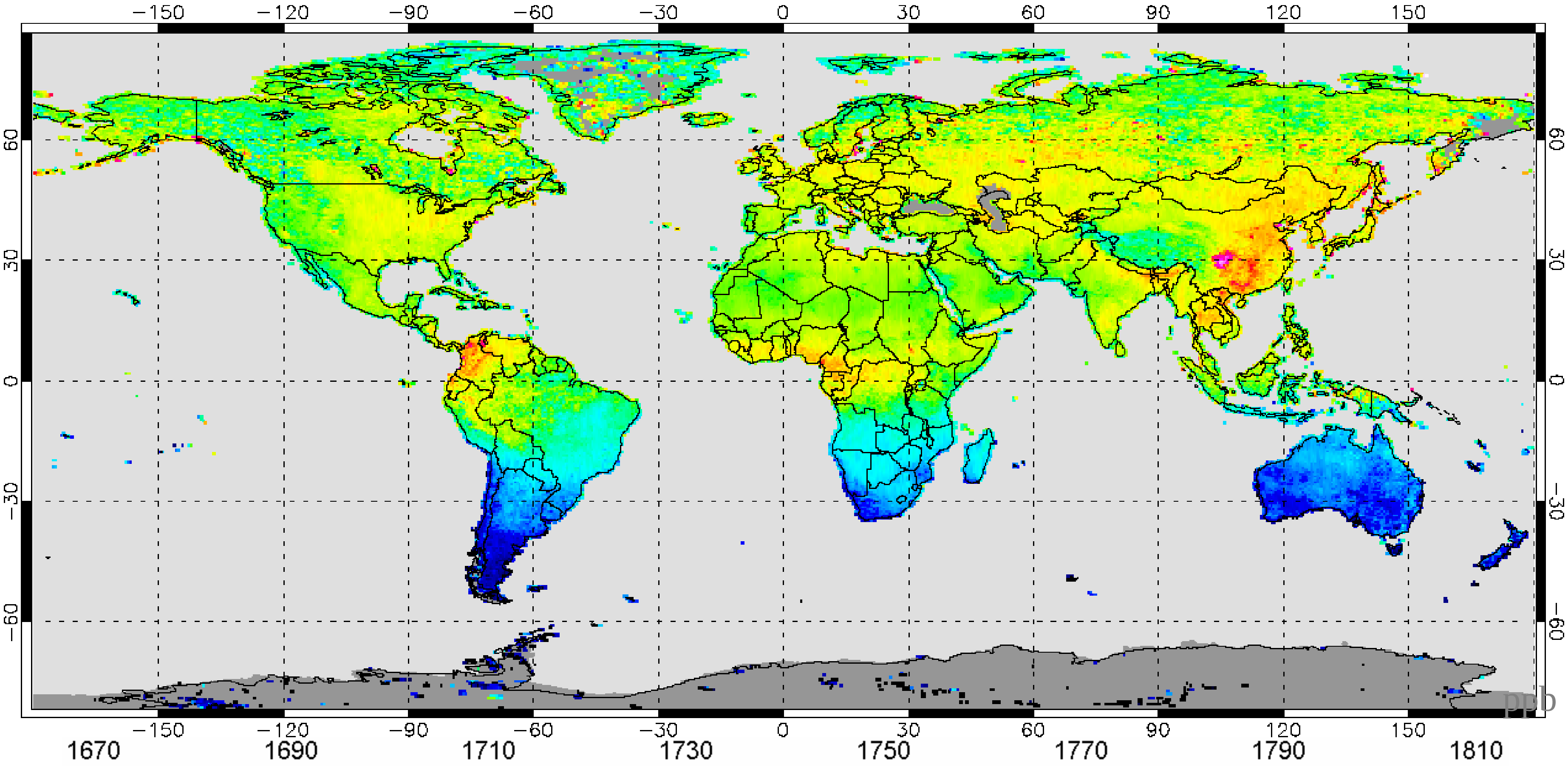
Operational monitoring air quality



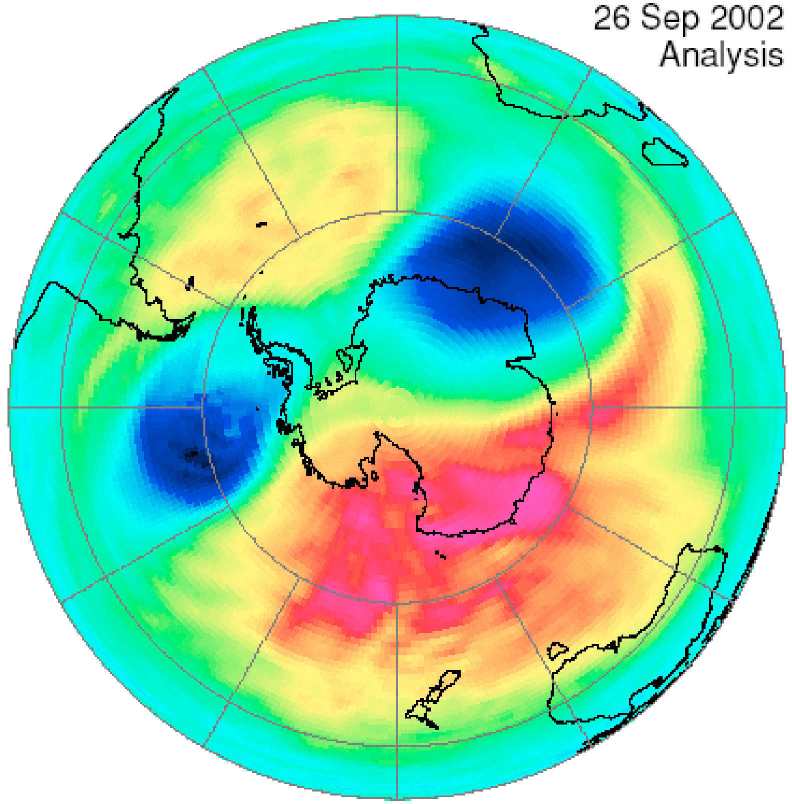


Climate monitoring

SCIAMACHY 2003/2004 methane concentration



Operational monitoring of the ozone layer



Ozone hole, vortex breakup, GOME, September 2002

Environmental themes, data usage, applications

Environmental Theme / Data usage	Ozone Layer & Surface UV radiation	Air Quality	Climate
Protocols	UNEP Vienna Convention; Montreal and subs. Protocols CFC emission verification Stratospheric ozone, halogen and surface UV distribution and trend monitoring	UN/ECE CLRTAP; EMEP / Göteborg Protocol; EC directives EAP / CAFE AQ emission verification AQ distribution and trend monitoring	UNFCCC Rio Convention; Kyoto Protocol; Climate policy EU GHG and aerosol emission verification GHG/aerosol distribution and trend monitoring
Services	Stratospheric composition and surface UV forecast NWP assimilation and (re-) analysis	Local Air Quality (BL); Health warnings (BL) Chemical Weather (BL/FT) Aviation routing (UT)	NWP assimilation and (re-) analysis Climate monitoring Climate model validation
Assessment **(lower priority for operational mission)**	Long-term global data records WMO Ozone assessments Stratospheric chemistry and transport processes; UV radiative transport processes Halogen source attribution UV health & biological effects	Long-term global, regional, and local data records UNEP, EEA assessments Regional & local boundary layer AQ processes; Tropospheric chemistry and long-range transport processes AQ source attribution AQ Health and safety effects	Long-term global data records IPCC assessments Earth System, climate, rad. forcing processes; UTLS transport-chemistry processes Forcing agents source attribution Socio-economic climate effects

Measurement strategy - example: climate protocol monitoring

Role of Satellite Measurements

- Concentration monitoring for inverse modeling of CH_4, CO_2, CO and NO_2 emissions
- Global concentration distributions of the mentioned gases, O_3 and aerosols

Role of Surface network

- Greenhouse gases trend monitoring (CO_2, CH_4, N_2O, SF_6, CF_4, HFCs)
- Weekly surface concentrations and total columns from a representative network.
- Validation of satellite measurements
- Concentration monitoring for inverse modeling of CH_4, CO_2, CO and NO_2 emissions
- Tropospheric O_3: sondes, lidar and surface data;
- Tropospheric aerosol optical depth and aerosol absorption optical depth
- Trend monitoring for ozone depleting substances with climate forcing: (H)CFCs.

Auxiliary data

- Meteorology from NWP centers including surface data
- Emission inventories and estimates on sinks

Mission concept for air quality - system options

Driving requirements (monitoring, forecast) :

Revisit time 0.5 – 2 h Spatial resolution 5 – 20km

System options:

A 1 geostationary satellite to satisfy spatial-temporal sampling requirements over Europe, and

1 LEO satellite in sun-synchronous orbit for global pollution transport (Convention on long-range transport of air pollutants, medium-range forecast)

B a constellation of ~3 satellites in inclined LEO to satisfy spatial-temporal sampling requirements globally at mid-latitudes, with reduced sampling at low latitudes

C 1 satellite in sun-synchronous LEO, with local time defined to complement Metop and NPOESS diurnal sampling (afternoon orbit)

Air quality:

LEO (MEO) constellation as a replacement for GEO ?

- GEO mission has best spatial-temporal sampling over Europe
- GEO mission only complete with additional LEO platform covering hemispheric pollution transport (CLRTAP convention)
- GEO mission fulfils temporal sampling requirement only over Europe – air quality services not available for most polluted regions (e.g. Asia)

- LEO/MEO constellation (~3 satellites) provides quasi-global coverage with good temporal sampling
- LEO/MEO constellation redundancy may be easier (loss of one satellite leads to degraded mission instead of complete failure; identical satellites; cheaper launch)

How to reach 2h revisit time at mid-latitudes with LEO/MEO constellation ?

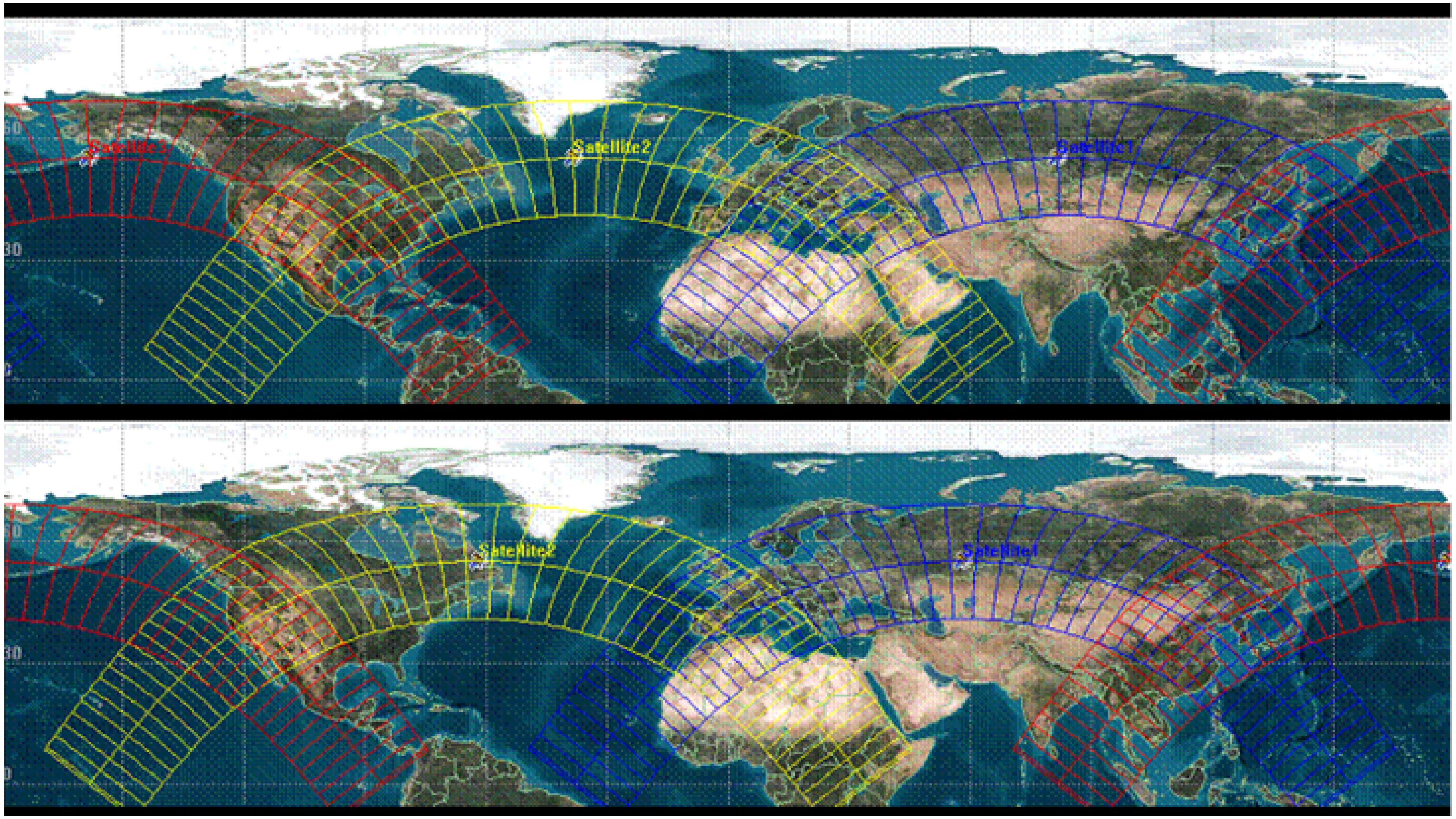
1. **Increase swath width by elevating orbit altitude**
   - 2h revisit time with 3 sun-synchronous satellites implies 3000 km orbit, at top of proton radiation level
   - 3.5h revisit time at latitudes > 30º realistic with 3 sun-synchronous satellites, 900km orbit.

   ⇒ **requirement not fulfilled.**

2. **Use inclined orbit (non sun-synchronous)**
   - orbit more efficient at inhabited latitude ranges
   - polar regions not covered
   - 3 satellites at 900km provide 1.7 hours revisit time at mid-latitudes (~35º… 65º) and reduced sampling at lower latitudes.

   ⇒ **possible solution. High orbit desirable.**

3 satellites at 900km, 125º inclination (two consecutive orbits)



Recommendation 1

Implement 1 LEO satellite with UV-VIS-SWIR payload for global air quality and climate protocol monitoring as soon as possible

- air quality applications develop quickly, SCIAMACHY and OMI/Aura demonstrating space contribution(eg NO_2), continuity issue arising
- climate protocol monitoring high on the agenda – continuity of SCIAMACHY CH_4 measurements, aerosol
- technology well demonstrated in space (GOME, SCIAMACHY, OMI; also TOMS, SBUV) – no technology specific failures
- 1 LEO platform common to all air quality system options; orbit-specific aspects need separate consideration

Recommendation 2

Perform trade-off between GEO+LEO and LEO constellation in inclined orbit, and implement complete air quality & climate protocol monitoring mission

Trade-off involves

- Level 2 error budgets on individual soundings
- spatial-temporal sampling under consideration of cloud
- end-user performance analysis
- maturity, cost and risk

Implementation:

launch of either GEO or remaining two inclined LEO platforms

Recommendation 3

Consolidate choice and requirements of instrument for UTLS mission for climate chemistry coupling and assessment applications, and implement the mission

- monitoring of ozone, climate and stratosphere-troposphere exchange
- NRT applications now in demonstration phase (MIPAS, Aura-MLS), new hypotheses on stratospheric precursors of weather patterns
- support to tropospheric missions via vertical resolution
- choice of instrument type (mm-wave or mid-IR limb-sounder) depends on priorities of applications
- prototype instrument specifications exist – need to be tailored towards operational applications

Capacity report available at ESA

Follow-up in Europe
EUMETSAT:
Operational monitoring atmospheric composition in post-EPS time frame 2015-2025
Based on user requirements defined in CAPACITY
Workshop with users March/April 2006

EU/ESA GMES, Sentinels 4/5 atmosphere ongoing